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The use of cyclododecane as an adhesive for temporary facings in paper conservation

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In recent years, cyclododecane (CDD) has been introduced into the book and paper conservation field as a temporary consolidant for flaking media and as a temporary fixative for water-sensitive media by the formation of a physical barrier against moisture. CDD is particularly suited to these two applications because of its insolubility in water and its ability to sublime without requiring the use of solvents for removal, leaving no residue on the object. This paper will explore a third possible use of CDD borrowed from the fields of archaeology and objects conservation: as an adhesive in the preparation of temporary facings. Various application techniques will be presented and compared. The effectiveness of the treatment will be addressed with a case study of two 18th-century ornithological gouache paintings on thin, brittle, torn paper fully adhered to acidic backing boards. Because of numerous risk factors involved, particularly during removal of the backing, the objects required the simultaneous consolidation of flaking pigment, the fixing of moisture-sensitive media, and the physical support of a temporary facing. Molten CDD was applied together with a facing layer of non-woven polyester, thus serving three functions at once and allowing the paintings to receive treatment with minimised risk.

1 Introduction

Cyclododecane (CDD) is a material sometimes used in paper conservation for the masking or temporarily fixing of moisture-sensitive media. Because of its hydrophobic properties, it protects the area where it is applied so conservation treatments involving moisture can be carried out. This practice is most often carried out in a small localised area, such as a signature, a stamp, or a detail in watercolour. Often the preferred delivery in paper conservation is to melt the CDD, which results in a formation of crystals more impermeable than those formed in films of CDD dissolved in a solvent (Stein *et al.* 2000). Melted CDD can be applied with a brush or a hot tool such as a kistka (a Ukrainian egg decorating tool made for drawing designs with melted wax). The hot tool causes the liquefied CDD to saturate the paper in the area applied. Because CDD sublimes in the air, it is a temporary and reversible fixative, and it does not require additional application of moisture or solvent to remove it.

Much less common in paper conservation is the use of CDD as a temporary adhesive, or as a full coating on the entire surface of the object. This paper will present a case study in which it was used for those purposes in the creation of a temporary facing.

2 Case study: two watercolour and gouache paintings

A pair of eighteenth-century watercolour and gouache paintings of birds was received for treatment (Figure 1). The paintings were ornithological studies by an unknown artist, labelled only with the captions *Red-headed Woodpecker of South Carolina* and *Blue Jay*. The images and painting style are nearly identical to two watercolours held in the University of South Carolina Libraries, part of a group of naturalist studies from a disbound sketchbook in the Ethelind Pope Brown Collection of South Carolina Natural History, a collection in the Irvin Department of Rare Books and Special Collections. The sketchbook has been tentatively attributed to John Laurens, an amateur artist of natural history in the second half of the eighteenth century (Makala no date).

The two objects had been painted in watercolour and gouache on laid paper that was cream coloured, and the inscriptions were written in iron gall ink (though no analysis was performed for identification). The papers were smooth and lightweight, more suitable for writing than for watercolour. The dimensions, though slightly uneven, were 450 mm × 285 mm. Both paintings were adhered overall to backing boards that

Figure 1 Two watercolour-gouache paintings on paper, adhered to acidic backing boards: a) *Red-headed Woodpecker of South Carolina*; b) *Blue Jay*.

appeared to be acidic wood pulp, and the primary supports were discoloured, stained and brittle, particularly at the edges. There were minor losses and tears, some of which were adhered to the board in misalignment. The surface of the paper was soiled with surface dirt and finger marks, and there were also areas of adhesive residue in the margins. The adhesive was determined to be animal glue by examination with UV light, under which it fluoresced lemon yellow, and it was found to be soluble in water.

The paper supports were fragile, and the media were even more so. There were numerous areas of cracking and flaking pigment where the thick gouache layers were cupping away from the paper, and there were small areas of media loss as well (Figure 2). Flaking was particularly prevalent in areas with glossy pigment, possibly because of a higher ratio of binder to pigment or because the artist had applied an additional coating of gum medium for visual effect. It is worth noting that in other areas the pigments were dry and underbound with too little binder instead of too much. Many of the glossy areas were painted directly over underbound areas that provided a poor substrate.

3 Proposed treatment

Because of the acidity and discolouration it caused, the backing needed to be removed. This treatment would also allow the objects to be mended and lined, and thus it was the highest priority of proposed treatment. However, it was also the most problematic. The objects would need to be laid face down for mechanical removal, threatening the

Figure 2 Details of flaking media: a) head of woodpecker; b) woodpecker foot and tree; c) tail of the blue jay with small losses; d) blue jay detail at ×50 magnification.

stability of the flaking pigments with pressure or abrasion. It would also be necessary to use moisture to soften the adhesive, posing a risk of solublising the sensitive watercolours. A third problem was the fragility of the thin, brittle paper, which had little physical strength to tolerate such a large treatment as backing removal.

It was decided that the pigments would be consolidated before backing removal, even though consolidation would not fully protect them from physical damage or contact with moisture. Gelatine was chosen as consolidant, as other consolidants such as Paraloid B72 were judged to be too glossy for the matte areas of pigment. To reinforce the strength of the paper, a temporary facing was proposed. This raised the question of which adhesive to use to attach the facing: it would have to be reversible, but not reversible in the same moisture used to remove the backing; and not necessitating the use of water, which might damage the watercolours. Other adhesives commonly used in paper conservation, such as

starch paste and cellulose ethers, would not work because of their water solubility. There were also concerns that solvent-based adhesives such as Paraloid B72 might darken the pigments and be difficult to remove due to the physical fragility of the media.

The solution was a temporary facing applied with CDD. Its characteristics would solve multiple problems at once: physical protection of flaking pigments, hydrophobic protection during the use of moisture, and the need for an adhesive for a temporary facing. Because of its ability to sublime, there would be no problem of reversibility as there might have been with a more conventional adhesive; it is essentially a self-reversing adhesive, consolidant and fixative. If it worked as hoped, it would be an ideal solution. The use of cyclododecane as an adhesive is uncommon in paper conservation, and rare but not unheard of in use with small local facings (Nichols and Mustalish 2002: 83). Slightly more common is its adhesive use in the fields of archaeology, paintings conservation and objects conservation, both with and without temporary facings (Caspi and Kaplan 2001; Rowe and Rozeik 2008).

4 Tests

Tests were performed to see if CDD would be feasible for use with a temporary facing. First, the method of application would need to be decided, and so several mock-ups were prepared for practice. After trying various methods of application, the best technique was found to be applying melted CDD directly to the surface using a soft hake brush. Techniques that were tested and rejected included melting the crystals directly on the surface of the paper using a heat spatula, which might damage the flaking pigments, and melting the crystals on the surface using a heat gun, which would be time-consuming. These latter techniques also left a more uneven surface, which could be hazardous to the paper once it was placed face down for backing removal. It would be found later that melting the crystals directly on the paper would also cause the CDD to penetrate too deeply into the paper and through to the backing, acting as an additional hydrophobic adhesive and making backing removal more difficult. Also rejected was the idea of using a solution of cyclododecane dissolved in solvent, because such a thin coating would not be a strong enough physical protection for the flaking media. Cyclododecane in solution is also less impermeable to moisture than it is when molten, due to a more open crystalline structure (Brückle *et al.* 1999).

The temporary facing material also had to be chosen. Various Japanese papers and non-woven polyesters were tested and the most suitable was found to be Reemay 2250, a smooth, thin material with an open fibre structure that allows the CDD to pass through, enveloping the polyester on both sides. Instead of a large single sheet of polyester, small overlapping pieces were used with the expectation that the CDD might sublime at different rates across the object, and the facing pieces might be removed one by one as they became free. Pieces were cut into strips approximately 4 cm wide, the same size as the hake brush used for CDD.

Tests were performed in adhering the facing strips to the mock-ups by laying them on the surface of the paper and brushing melted CDD through them. However, it was found that the strips adhered better if the surface was first brushed with a layer of cyclododecane before applying the strips, then more layers of CDD were brushed over the facing as reinforcement.

The CDD crystals were melted in a glass beaker on a warming plate. A small, inexpensive household mug warmer was used, which did not have a temperature gauge or rheostat. If the CDD was applied while too hot, it tended to penetrate the paper too deeply, but if it cooled on the brush for too long, it would become viscous and would not brush out properly, so much practice was required in application. The brush would be dipped in the beaker of melted CDD, then lifted for a momentary pause before brushing it onto the paper. Polyester was then applied and the CDD brushed through it.

5 Treatment

The objects were surface cleaned with a soft brush. Fragile pigment was consolidated with a solution of gelatine in deionised water. An ultrasonic mister was used to apply a 1% solution of gelatine to both the underbound and the flaking areas of paint (Maheux and McWilliams 1995). The fine mist not cause any perceived solubilisation of the watercolours. It

was found to have a slightly darkening effect on the underbound pigment, but the consolidation was deemed a necessary precaution. However, the mist did not effectively consolidate the flaking pigment. Even with the small droplet size produced by the ultrasonic mister, the gelatine rested on the surface of the flakes rather than going into the spaces under and between them. Application was switched to a small watercolour brush, now using a 3% gelatine solution warmed on the mug warming plate. The conservator used a microscope to apply the solution directly into the cracks between the flakes, occasionally dipping the brush into ethanol as well to aid the penetration. Cupping flakes were gently pressed into plane once they had softened from contact with the gelatine. This consolidation would protect the areas of fragile pigment from any physical disruption in the initial brush application of CDD.

After the areas of fragile pigment were consolidated, the temporary facing of CDD and polyester was applied as described above. Because the backing removal was expected to be a lengthy process, several coats of CDD were used to ensure that it did not sublime too early.

The technique was as follows:

1. Brush melted CDD on entire surface, taking care not to let it penetrate through the paper to the backing board. Apply a second or third coat as needed.

2. Apply small pieces of polyester, one at a time, overlapping by a few millimetres.

3. Brush melted CDD through and over the polyester, sealing it onto the surface of the previous coating. Apply a second or third coat as needed.

Overall, the temporary facing was successful. The woodpecker painting was the first to be given the temporary facing, and its application was slightly more problematic than on the blue jay painting. With the latter, the conservator was more attuned to the specifics of temperature, speed and motion, and thus the facing application was better. On the woodpecker painting, there were areas where the CDD managed to penetrate the paper and go through to the backing, making a temporary hydrophobic adhesive that held parts of the backing

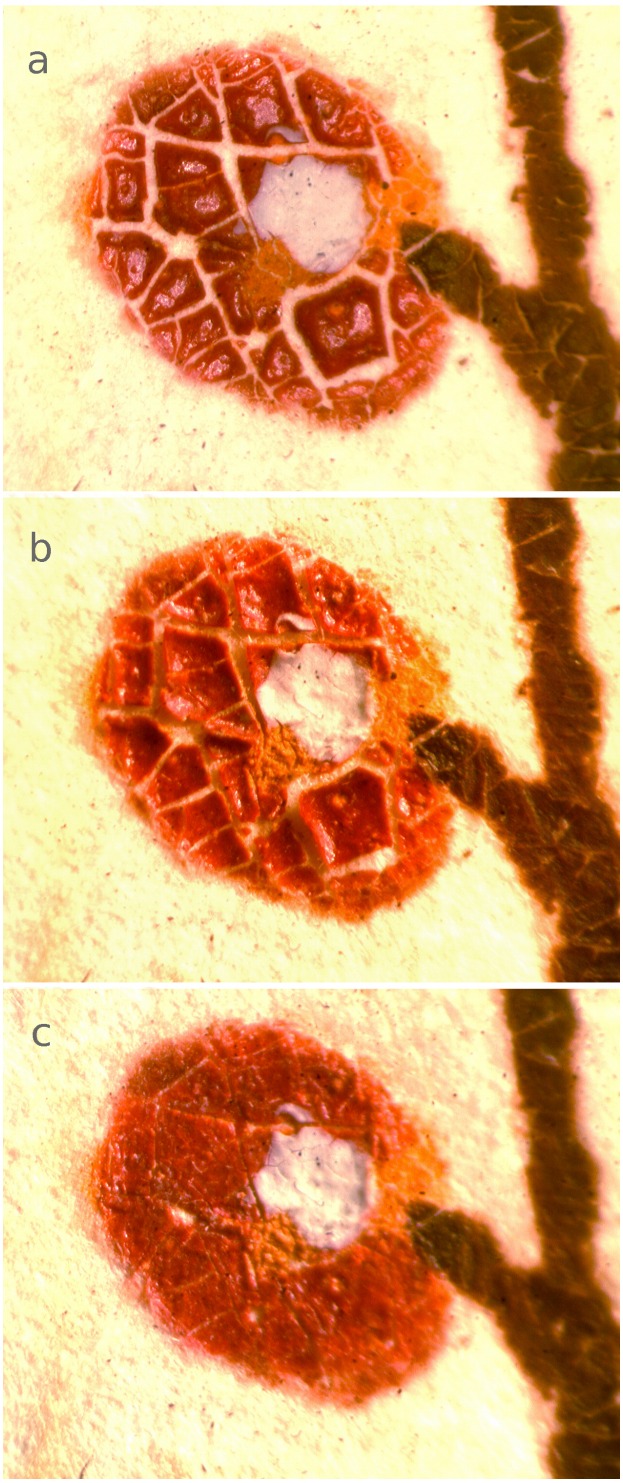

Figure 3 Details of a berry from the *Blue Jay* painting at ×50 magnification: a) before consolidation; b) before consolidation, raking light; c) after consolidation.

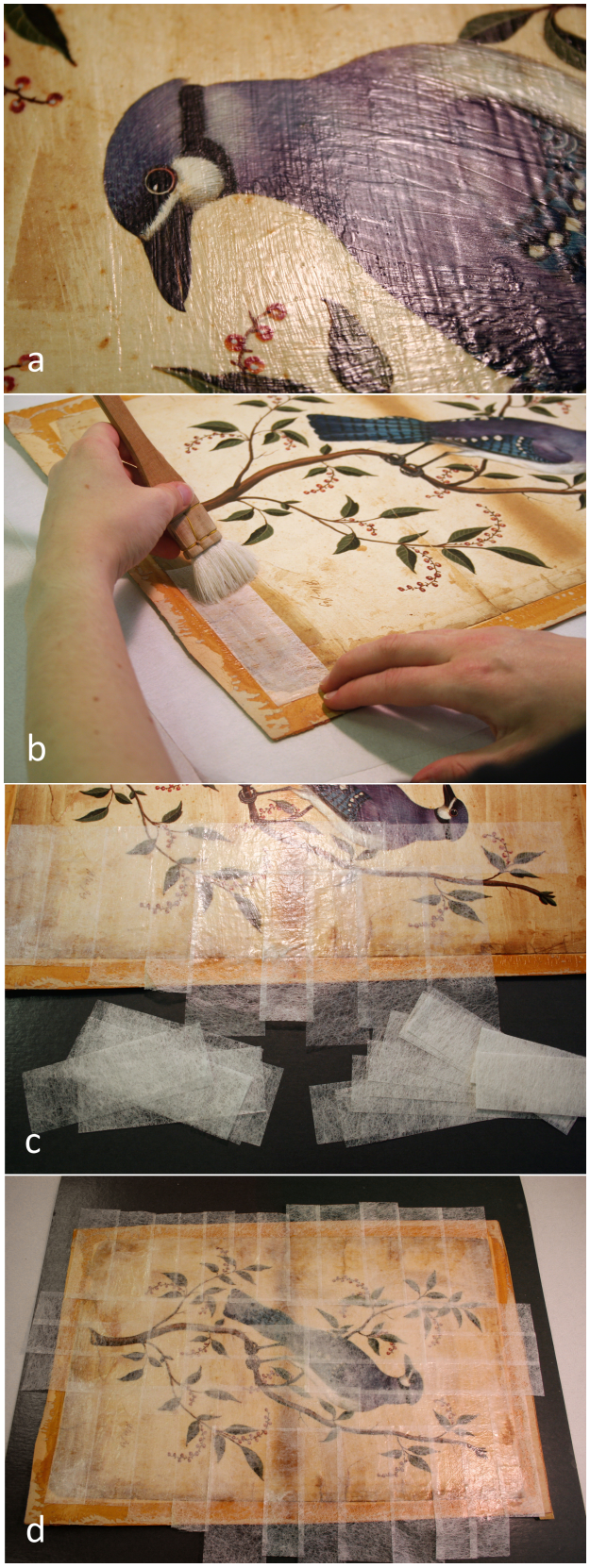

Figure 4 Steps of the temporary facing: a) entire surface of the object brushed with CDD; b) small pieces of nonwoven polyester applied and CDD brushed through; c) additional overlapping pieces applied; d) the temporary facing completed.

Figure 5 Verso of woodpecker painting: a) during backing removal, with CDD excessively penetrating the paper and parts of backing, with possible pigment migration. The paper is translucent in areas saturated by CDD; b) after treatment.

board to the paper. Those areas had to be left to sublime before those segments of backing could be removed. There were also areas where it appeared that the underbound pigments might be solubilising or migrating in the hot, liquid CDD.

To prepare for backing removal, the objects were placed face down on a sheet of acrylic glazing (Plexiglas) and the edges of the board were taped to the acrylic to ensure that the objects did not move. The conservator worked on a light table, which was particularly important in the latter stages of backing removal. The outer layers of the backing were then removed mechanically by paring with a scalpel. When only the final few layers remained still adhered to the objects, a poultice of Laponite RD was applied to introduce enough moisture to soften the adhesive, and pieces of the backing were able to be peeled away. Existing mends were removed in this same manner. Residual adhesive was removed with cotton swabs and moisture. As damaged areas of the paper were exposed, mends of lightweight Japanese paper were applied with wheat starch paste. In cases where the tears were still out of alignment, those mends were temporary, to be replaced later.

When the backings were fully removed, the objects were left to allow the CDD to sublime. Because of the multiple coatings, the CDD was slow to sublime, so the process was aided by the use of a heat press ordinarily used for dry mounting. The press was located in a large, open conservation studio with general air circulation. The objects were not

Figure 6 Sublimation taking place in an open heat press.

pressed, but they were allowed to lie on the bed of the open press while the hot platen was suspended above, radiating heat to the objects below. The temperature was set to 125 °C, but the heat radiating down to the objects was significantly less. The CDD did not melt to a liquid, but the heat accelerated its sublimation from the solid state. The objects were placed in the open heat press each day for approximately eight hours until sublimation was complete, which occurred within a week.

After sublimation of the CDD, the objects were now highly cockled due to the moisture used during the backing removal, the presence of misaligned tears, and the absence of the rigid boards that had held them flat for so long. The paintings were relaxed slowly in a humidity chamber and flattened. Because of their extensive cockling and fragile pigments, a 'hard–soft sandwich' technique was used to flatten them, consisting of a sheet of mat board beneath and layers of polypropylene fleece above, pressed with boards and heavy weights (Homburger and Korbel 1999).

Once they were suitably flattened, the paintings were mended with Japanese paper and wheat starch paste. Losses were filled with matching toned Western papers or with toned leafcast papers made for the purpose with pulp of suitable colour. Tears that had been misaligned were coaxed back into their original positions. One area of image loss was retouched (the top of the tree trunk in the woodpecker painting). Slightly dampened cotton swabs were used to reduce local areas of staining.

Because the paper was so brittle, it was decided that the objects should be lined with Japanese paper. Lightweight 5 gsm Tengujo was chosen for the linings. A solution of 3% Klucel G in ethanol was chosen as the adhesive for its quick drying properties without the need of water and its ability to penetrate the Japanese paper. It would also penetrate the primary support of the object itself, acting as a sizing agent to strengthen the paper. The paintings were relaxed in a humidity chamber and laid face down on a sheet of smooth non-woven polyester. A sheet of dry Tengujo was laid directly onto the verso of the object. A sheet of fibreglass screen was laid over the Tengujo, and the adhesive was brushed through the screen, penetrating the Japanese paper and adhering it to the object. The screen was then removed and an additional coating of Klucel G was applied to ensure adhesion of the lining. The objects were then flattened again in the 'hard–soft sandwich'.

After flattening, the objects were returned to the client to be mounted in cotton rag window mats and framed.

6 Observations

It has been mentioned that areas of unbound pigment in the woodpecker painting had appeared to solubilise or migrate in the initial application of CDD. After sublimation, those pigment areas developed a slightly soft, flocked velvet appearance like loose powdered pastel. It is surmised that the pigment particles were so underbound that the liquid CDD was able to lift individual particles from the paint surface and redistribute them, much like a glacier redistributing earth and rocks. It may also be that the liquid CDD filled spaces between the pigment particles and then left voids when it sublimed. A third possibility is that during sublimation, the CDD layer lifted from the surface, cleaving from the paint layer and disturbing particles. After the CDD sublimed, the loose particles settled on the surface again, but only lightly. These areas were consolidated yet again using the 3% gelatine solution and the ultrasonic mister. This occurrence has not been observed by the author in other applications of CDD, and it may be unique to thick layers of underbound fine pigment. The composition of the specific pigments is not known, but the red pigment appeared most affected.

In an attempt to recreate this phenomenon, the author prepared samples of Winsor & Newton wa-

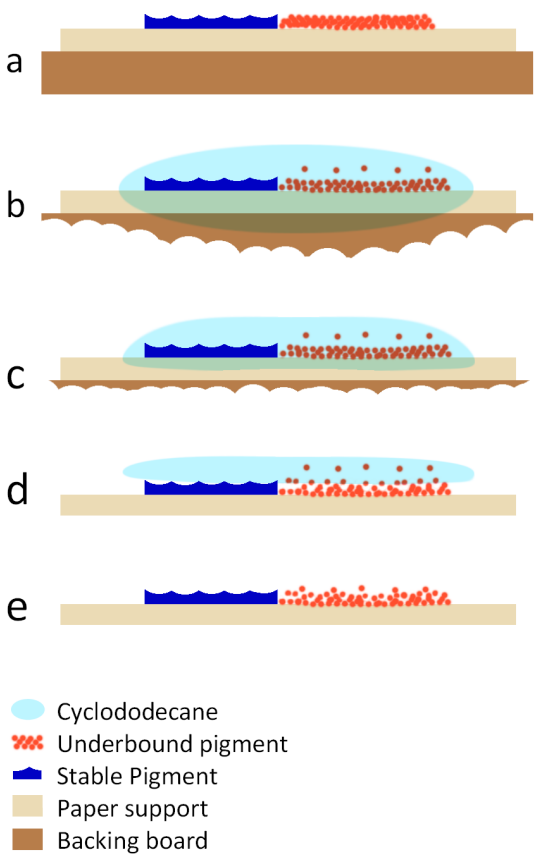

Figure 7 The possible mechanisms of migration and 'flocking' of underbound pigment: a) the object before treatment; b) CDD is applied, disturbing some unbound pigment particles and penetrating the paper and backing board, preventing its removal; c) CDD has partially sublimed. Backing can be removed. Disturbed pigments are still suspended; d) CDD sublimes further, slightly lifting from the surface and carrying more pigment particles; e) CDD has fully sublimed. Disturbed pigment particles redistribute on the surface, causing a velvety flocked appearance.

tercolour mixed with powdered Rembrandt pastel to mimic the underbound pigment areas. Samples were painted onto cotton rag mat board and then coated with increasingly thick layers of CDD. A heat gun was then used to cause the CDD to melt and to sublime, giving it plenty of opportunity to penetrate the pigment layer and to cause migration. Rather than causing all of the CDD to sublime, the author allowed it to drip across the surface of the mat board. It was visually evident from the colours present in the dripped areas that the hot liquid had transported pigment particles. The flocked appearance in the paint layer was not replicated, however.

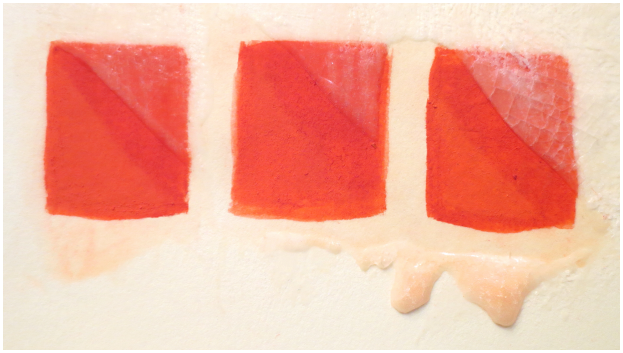

Figure 8 Samples prepared with a mixture of watercolour and dry pastel to imitate underbound pigments. Samples have been coated with increasingly thick layers of CDD from left to right. CDD has been melted and partially sublimed with a heat gun, causing it to liquify and carry migrating pigment particles.

7 Conclusion

The CDD temporary facing was successful, providing protection for vulnerable flaking pigments, moisture sensitive media and physically fragile paper, thus facilitating the removal of damaging backing boards. The use of CDD as an adhesive for temporary facings is quite different from its use as a local fixative in paper conservation treatments. In its use as a fixative, CDD must fully saturate the pigment and penetrate the paper for full protection from moisture. But in its use as a surface coating and adhesive for a temporary facing, care must be taken to avoid over penetration of the primary support if there is to be a backing removed. Care must also be taken to avoid disturbing media that might become friable, solubilised, or dispersed. More study is needed to examine the mechanism and possible hazards of its penetration of underbound paint films. More practice, experimentation and cross-disciplinary collaboration is also encouraged for improvement on the techniques presented here for its use in temporary facings.

Biography

Grace White received her MA in paper conservation at Northumbria University in Newcastle-upon-Tyne, UK. She has worked at Etherington Conservation Services in Greensboro, North Carolina, USA, and in the conservation department at Duke University Libraries in Durham, North Carolina. In 2009, Grace received grants from the Foundation of the American Institute of Conservation and the Rasmuson Foundation to travel to museums across Alaska, providing paper conservation treatments and training. She currently resides in Chapel Hill,

Figure 9 The paintings after treatment.

North Carolina, where she is Paper Conservator at the Ackland Art Museum at the University of North Carolina and in her private practice, Paperwhite Art Conservation.

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Material list

- Reemay 2250, Klucel G, wheat starch, thin Tengujo (5 gsm), hake brush, P-15 (thick) Pellon polyester batting, rag mat board, gelatine (photographic grade type B), all from Talas, talasonline.com
- Cyclododecane, Kremer, www.kremer-pigmente.com
- Mr Coffee mug warmer, Vicks ultrasonic humidifier, Bienfang/Seal Masterpiece 210M dry mounting/laminating press, all from Amazon www.amazon.com
- Fibreglass insect screening, rare earth magnets, other components for ultrasonic mister, all fromMcMaster Carr, www.mcmastercarr.com
- Ethanol, Fischer Scientific, www.fishersci.com
- Rembrandt pastels, Winsor and Newton watercolours, watercolour brushes, all from Dick Blick, www.dickblick.com

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